

# Experimental proposal to study the excess at $M_{jj} = 150$ GeV presented by CDF at Fermilab

D. Bettoni<sup>1</sup>, P. Dalpiaz<sup>1</sup>, P. F. Dalpiaz<sup>1</sup>, M. Fiorini<sup>1</sup>, I. Masina<sup>1</sup>, G. Stancari<sup>1,2</sup>

<sup>1</sup> *Dip. di Fisica dell'Università di Ferrara and INFN Sez. di Ferrara,*

*Via Saragat 1, I-44122 Ferrara, Italy*

<sup>2</sup> *Fermi National Accelerator Laboratory,  
Batavia, IL 60510, USA*

## Abstract

We propose an experimental test to verify the unexpected excess at  $M_{jj} = 150$  GeV presented by the CDF collaboration in the invariant mass distribution of jet pairs produced in association with a W boson. We propose a formation experiment in which the energy range of the  $M_{jj}$  excess is scanned with proton-antiproton interactions at the Tevatron.

The excess at  $M_{jj} = 150$  GeV in the invariant mass distribution of jet pairs produced in association with a W boson, recently presented by CDF collaboration [1] was a big surprise. The reported cross section is 300 times larger than expected for this channel in the frame of the Standard Model. This result needs an experimental confirmation. The CDF collaboration has already data to double the statistics and when the analysis is completed we will know whether the effect is confirmed.

We propose an independent experimental validation of this effect, scanning the observed bump in  $M_{jj}$ , *in formation* in  $p\bar{p}$  interactions, setting the Tevatron energy in the range of the  $M_{jj}$  excess.

An important feature of formation experiments is that the energy resolution is given by the momentum resolution of the beams. The spectrometer is used only in the trigger, to select the events. This experimental technique has been successfully exploited by many experiments for the study of hadron spectroscopy: in particular it was used to study the charmonium spectrum by three experiments: R704 [2] at the CERN ISR, and E760 and E835 [3] at the Fermilab antiproton accumulator. The same technique will be used by the PANDA experiment at the future FAIR facility [4].

This kind of experiments is analogous and complementary to the study of resonances *in formation* in  $e^+e^-$  colliders. It must be noted, however, that in  $e^+e^-$  annihilation direct formation is limited to the states with the quantum numbers of the photon ( $J^{PC} = 1^{--}$ ), whereas in  $p\bar{p}$  formation all the states with any (non-exotic) quantum numbers can be formed directly. As a consequence, in  $p\bar{p}$  annihilation the background is higher with respect to  $e^+e^-$ . Furthermore, the cross section, that is  $1\mu\text{barn}$  in the reaction  $p\bar{p} \rightarrow J/\Psi$ , decreases very rapidly with the mass of the resonances if the photon exchange dominates the process.

On the other hand, the hadronic background problem can be very effectively overcome by looking at specific final states. In fact, this technique is very useful when the widths of the states analyzed are narrow and the signature clear, allowing a very precise measurement of the masses and widths.

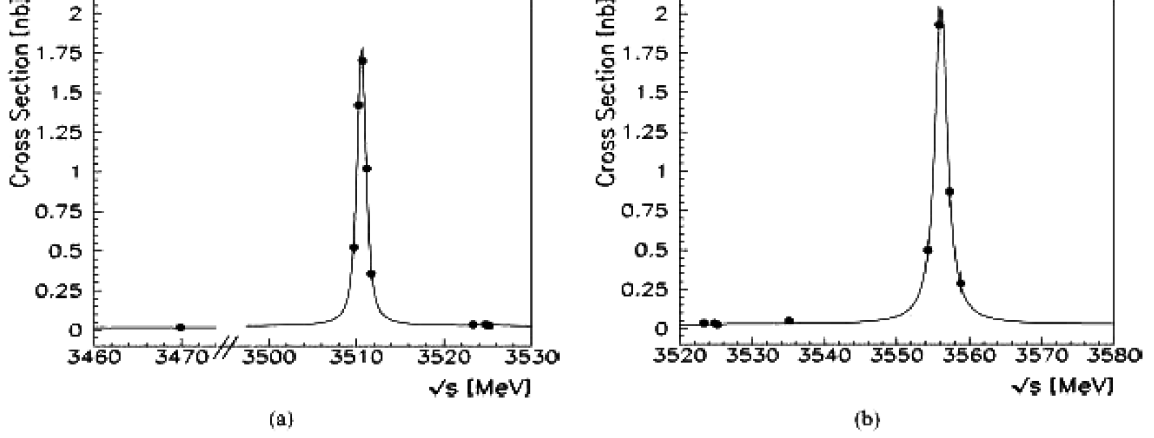


FIG. 1: E835 measurements [5] of the cross section as a function of the center-of-mass energy for the  $\chi_{c1}$  (a) and  $\chi_{c2}$  (b) charmonium states via the process  $p\bar{p} \rightarrow \chi_c \rightarrow J/\Psi + \gamma \rightarrow e^+ + e^- + \gamma$ .

This is clearly demonstrated in Fig. 1, which shows the E835 scans of the  $\chi_{c1}$  and  $\chi_{c2}$  charmonium states via the process  $p\bar{p} \rightarrow \chi_c \rightarrow J/\Psi + \gamma \rightarrow e^+ + e^- + \gamma$ , where the reaction is triggered only by the electron pair [5]. The experiment was performed at the Fermilab antiproton accumulator with an internal hydrogen jet target. The energy scans were carried out varying the antiproton beam momentum in small steps. The excellent beam momentum resolution of  $2 \times 10^{-4}$  allowed E835 to produce the most precise measurements of the masses and widths of these very narrow states. The figure also shows the excellent signal-to-noise ratio which can be obtained in this kind of formation experiments triggering on exclusive final states with a clear signature.

The suggestion to scan the observed bump in  $M_{jj}$ , setting the Tevatron energy in the range of the  $M_{jj}$  excess, is therefore straightforward.

We observe, however, that the Tevatron energy ranges between 300GeV and 2TeV. At the Tevatron injection energy of 150GeV per beam, one can expect an initial instantaneous luminosity of  $3 \times 10^{31} \text{cm}^{-2}\text{s}^{-1}$  and an average luminosity of 6 events/(pb week), taking into account beam lifetimes, emittance growth, and turn-around time. At injection, the relative beam momentum spread is  $5 \times 10^{-4}$ . This spread means 300MeV energy resolution.

At lower energies, as 150 GeV, it is possible to operate the Tevatron, but a particular machine development is necessary. Also the foreseen luminosity decreases by a factor 2.

Many theoretical interpretations of the  $M_{jj}$  excess have appeared in the last month. One of the first, proposed by Eichten et al. [6], consider the  $M_{jj}$  excess in the Technicolor framework. The authors identify the  $M_{jj}$  excess as the techni-pion,  $\pi_T$ . Within this model the  $\pi_T$  is the decay product of a resonance with  $I^G J^P C = 1^+ 1^- -$ , the techni-rho vector meson,  $\rho_T \rightarrow W\pi_T$ , with  $M_{\rho_T} = 290 \text{ GeV}$ . The  $\pi_T$  decays in two jets. This model takes into account the fact that the  $M_{jj}$  excess is not seen in experiments with leptons, the quark b are absent in the decay jets and the cross section is 300 times larger than the expectation of the Standard Model.

We propose to test this theoretical hypothesis, searching for the formation reaction of the techni-rho vector meson:  $p\bar{p} \rightarrow \rho_T$ ,  $\rho_T \rightarrow W\pi_T$ . This is possible, setting the Tevatron near the injection

energy and scanning around 290GeV, triggering on  $[e(\mu)]$  produced in the  $W$  decay, and the jet pairs  $[jj]$  from the techni-pion,  $\pi_T$ , decay. Notice that the  $W$  produced in the decay is nearly monochromatic and longitudinally polarized. The  $e$  and  $\mu$  produced in the  $W$  semileptonic decays have then an energy spectrum, approximately proportional to  $x(1-x)$ , where  $x = E/E_W$ ,  $E$  is the energy of the  $e(\mu)$  and  $E_W$  is the energy of the  $W$ . These features, a clear signature of the searched events, used in the trigger and in the subsequent analysis, will greatly improve the background reduction.

Obviously, the cross section of the hypothetical reaction  $p\bar{p} \rightarrow \rho_T$  is unknown. From CDF evidence, however, we know that at 2TeV energy, the cross-section should be around  $4pb$ . Taking this cross-section value for our process, CDF or D0 will collect each 24 events a week. If the techni-rho is, as expected, narrower than 1GeV, it is possible to overcome the background also with some lower cross section.

The experimental test could be done at Tevatron using CDF and D0 detectors without modifications, with a reliable luminosity monitor. It may be observed that, in this case, the consumption of electric power and helium is lower than in the normal running at high Tevatron energy.

When it will be possible to set the Tevatron energy at 150GeV, and scan around the CDF observed  $M_{jj}$  bump, triggering on collinear jets  $[jj]$ , a direct independent validation of the CDF observed bump in  $M_{jj}$  could be realized.

Concluding, we observe that the Tevatron has a unique possibility to test this new physics in short times.

- 
- [1] T. Aaltonen *et al.* [CDF Collaboration], *Invariant Mass Distribution of Jet Pairs Produced in Association with a  $W$  boson in  $p\bar{p}$  Collisions at  $\sqrt{s} = 1.96$  TeV*, Phys. Rev. Lett. **106** (2011) 171801 [arXiv:1104.0699 [hep-ex]]. See also: V. Cavaliere, Ph.D. Thesis. University of Siena, FERMILAB-THESIS-2010-51 (2010).
  - [2] C. Baglin *et al.* [ R704 and Annecy(LAPP)-CERN-Genoa-Lyon-Oslo-Rome-Strasbourg-Turin Collaborations ], *Formation Of The  $\chi(1)$  And  $\chi(2)$  Charmonium Resonances In Anti-proton - Proton Annihilation And Measurements Of Their Masses And Total Widths*, Phys. Lett. **B172** (1986) 455.
  - [3] T.A.Amstronget *al.*, *Precision measurements of Charmonium states formed in  $p\bar{p}$  annihilation* Phys.Rev.Lett. **68**(1992) 1468  
G.Garzoglioet *al.*, *Experiment E835 at Fermilab*, Nucl. Instrum. Meth. **A519** (2004) 558-609.
  - [4] M. F. M. Lutz *et al.* [PANDA Collaboration], *Physics Performance Report for PANDA: Strong Interaction Studies with Antiprotons*, arXiv:0903.3905 [hep-ex].
  - [5] M. Andreotti,*et al.*, *Measurement of the resonance parameters of the  $\chi_1(1^3P_1)$  and  $\chi_2(1^3P_2)$  states of charmonium formed in  $p\bar{p}$  annihilations*, Nucl. Phys. **B717** (2005) 34-47. [hep-ex/0503022].
  - [6] E. J. Eichten, K. Lane and A. Martin, *Technicolor at the Tevatron*, arXiv:1104.0976 [hep-ph].